



U.S. Army School of Aviation Medicine

Noise & Vibration in Army Aviation

Terminal Learning Objective

- ◆ Action: Protect yourself from the effects of noise and vibrations in army aviation
- ◆ Conditions: Given lists of noise and vibration effects, terms, and definitions
- ◆ Standards: IAW TC 3-04.93 (chap 7), AR 40-501, DA PAM 40-501, and Fundamentals of Aerospace Medicine



Administrative Information

- ◆ Risk Assessment: Low
- ◆ Environmental Considerations: None
- ◆ Safety Considerations: None
- ◆ Evaluation: 50 Question exam at the end of Aeromedical Training at USASAM

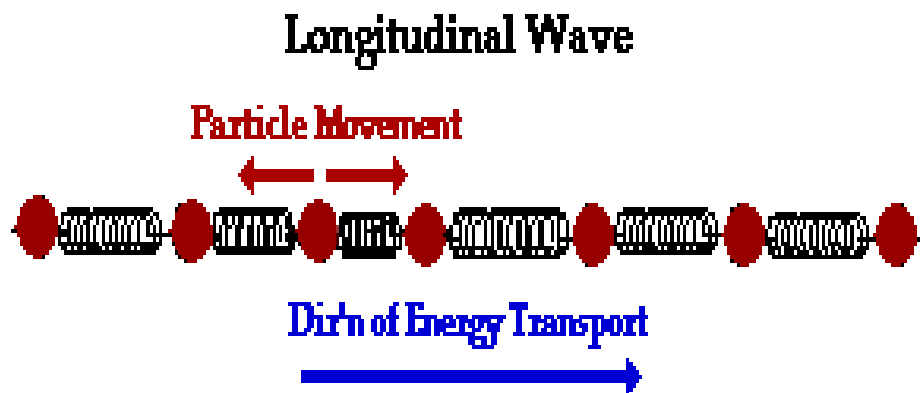
ELO A

- ◆ Action: Identify terminology associated with sound
- ◆ Condition: Given a list of definitions
- ◆ Standard: Without error, identify terms related to sound IAW TC 3-04.93



The Nature of Sound

Sound is mechanical radiant energy that is transmitted by longitudinal pressure waves in a material medium (such as air) and is the objective cause of hearing.

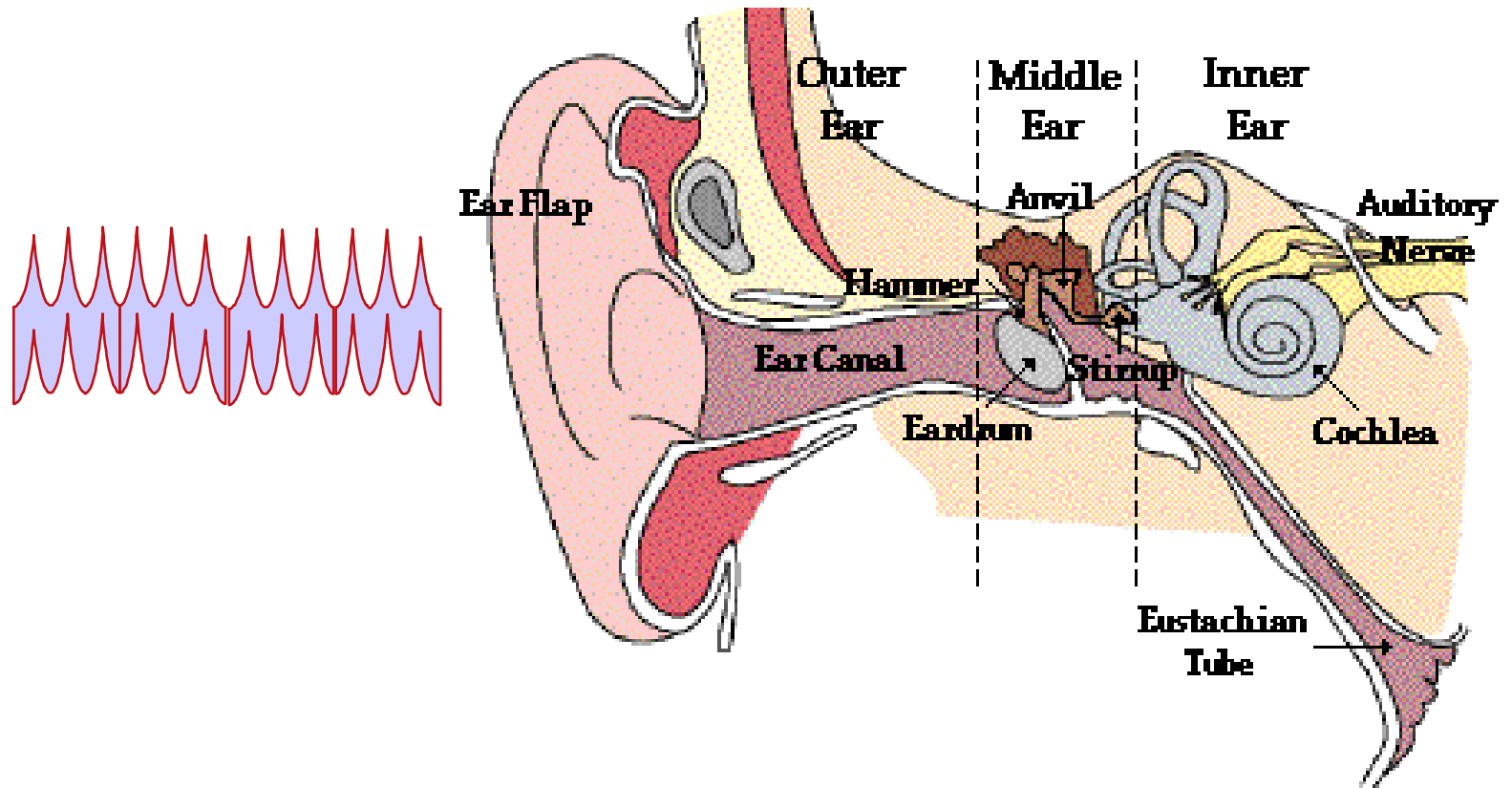


Sound

- ◆ Produced when an object or surface vibrates rapidly
- ◆ Transmitted through any elastic substance such as air, water, or bone
- ◆ Density of the substance determines the speed at which the sound and pressure waves will travel



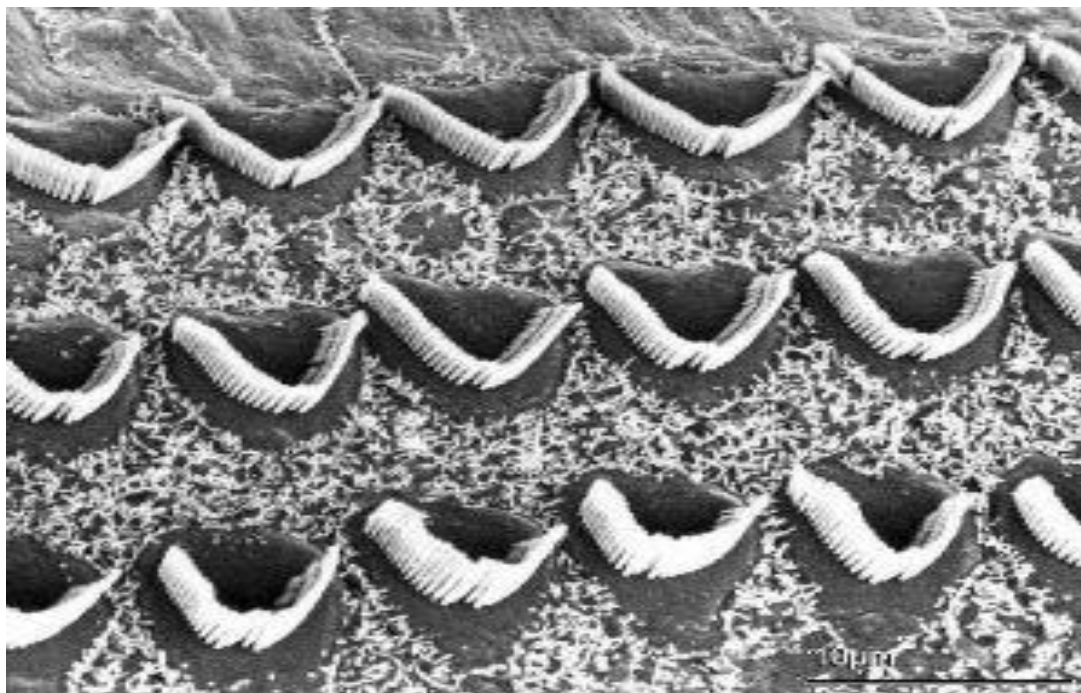
Perception of Sound



Cochlea



Receptors of Sound



- ◆ Detect fluid movement in the cochlea
- ◆ Transmit electrical impulses to the brain where sound is interpreted

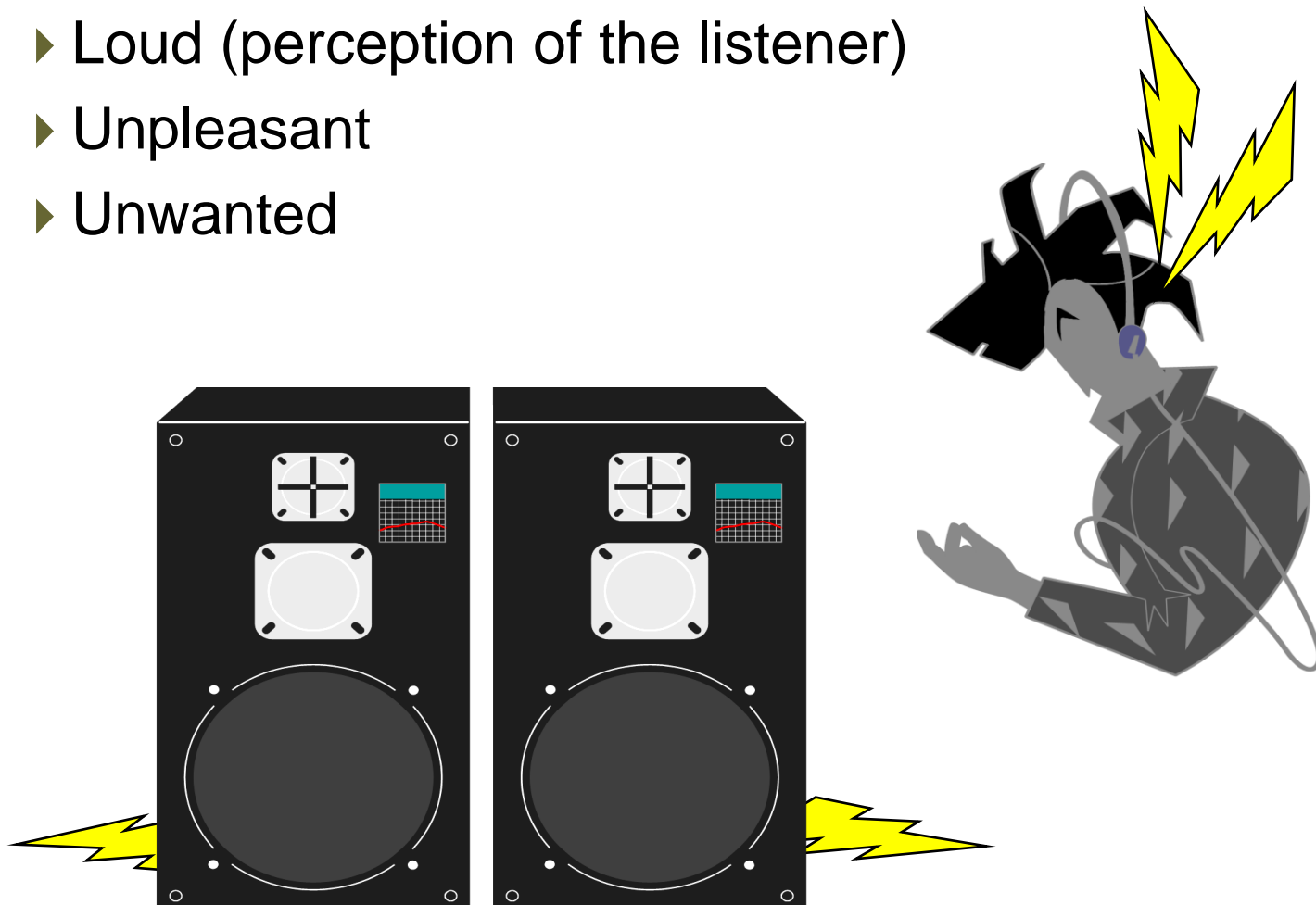
ELO B

- ◆ Action: Identify the effects of noise on the body
- ◆ Condition: Given a list
- ◆ Standard: Identify the effects of noise on the body, IAW TC 3-04.93



Noise

- ◆ Sound that is:
 - ▶ Loud (perception of the listener)
 - ▶ Unpleasant
 - ▶ Unwanted



Effects of Noise in Aviation Environment

- ◆ Annoyance & fatigue
- ◆ Speech interference
- ◆ Hearing loss



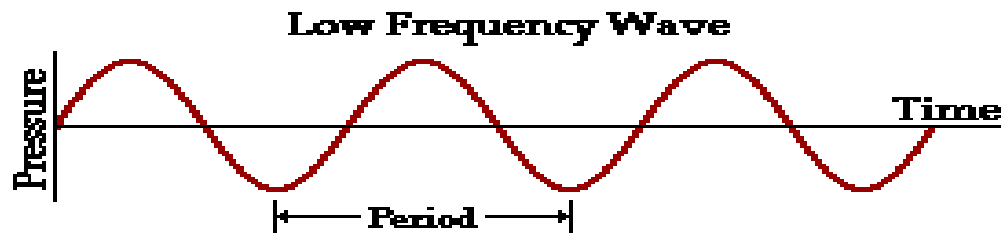
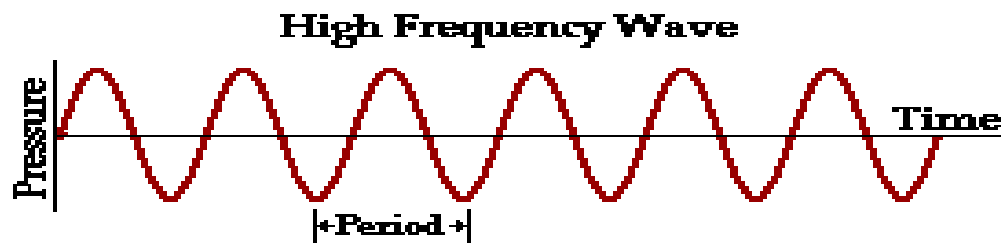
Measurable Characteristics of Noise

- ◆ Frequency
- ◆ Intensity
- ◆ Duration



Frequency

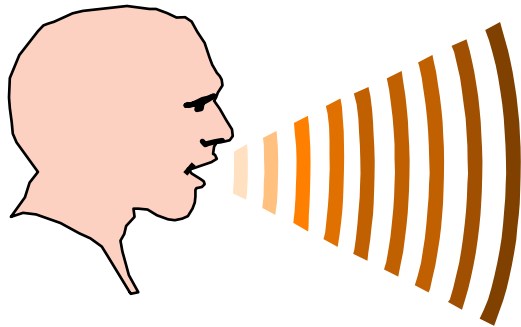
- ◆ Gives sound the quality of pitch
- ◆ Number of times per second the air pressure oscillates
- ◆ CPS = Hertz (Hz)



Frequency Ranges



Human hearing: 20 to 20,000 Hz



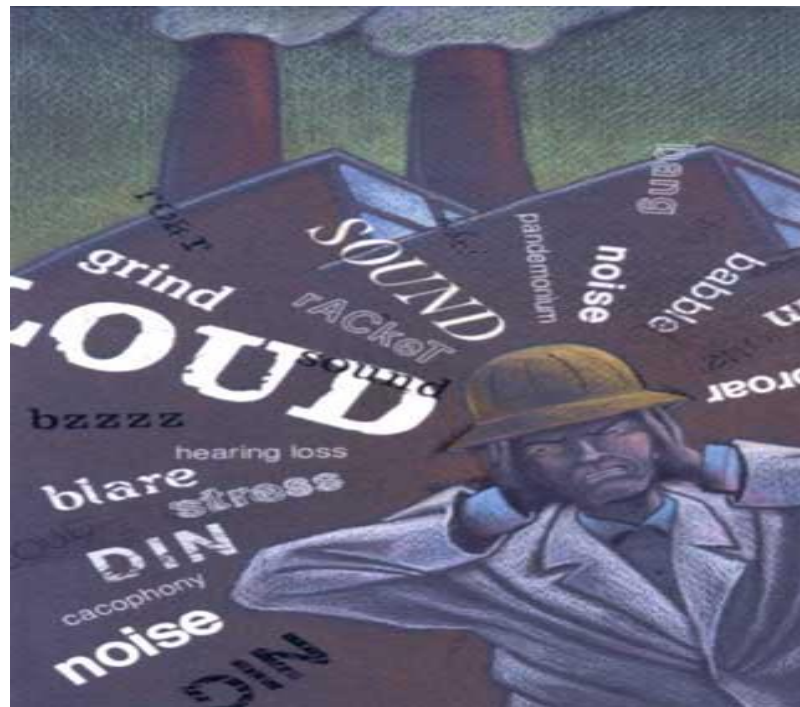
Speech: 200 to 6,800 Hz



Speech intelligibility: 300 to 3,000 Hz

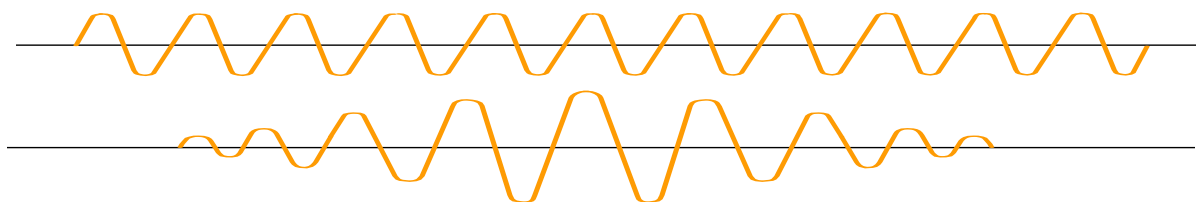
Intensity

- ◆ A measure that correlates sound pressure to loudness
- ◆ Measured in decibels (dB)



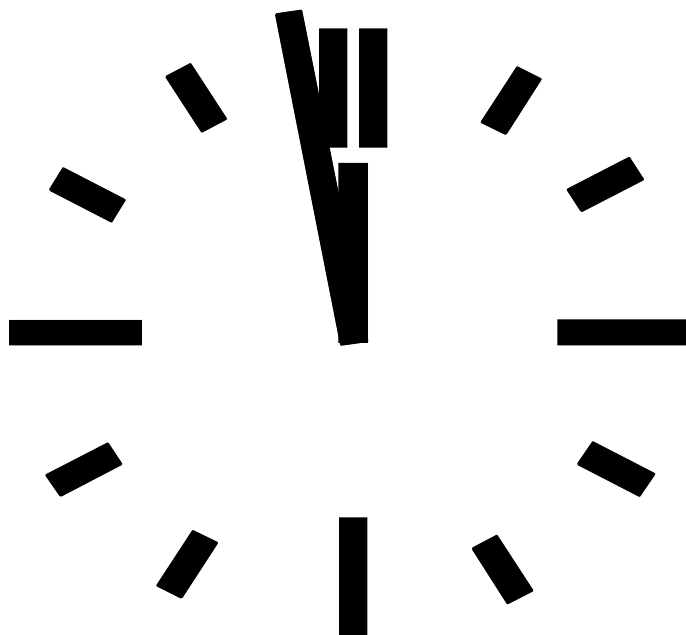
Decibel Levels

- ◆ 0 dB - Threshold of hearing
- ◆ 65 dB - Average human conversation
- ◆ 85 dB - Damage-risk noise limit
- ◆ 120 dB - Threshold for discomfort
- ◆ 140 dB - Threshold of pain
- ◆ 160 dB - Ear drum rupture



Duration

- ◆ How long you are exposed to noise
 - ▶ Steady noise
 - ▶ Impulse noise



Steady Noise



- ◆ Continuous noise at high intensity
- ◆ Wide range of frequencies
- ◆ Most encountered in Army aviation
- ◆ Engines, drive shafts, transmissions, rotors and propellers

Impulse Noise

- ◆ Explosive noise
- ◆ High intensity with low duration
- ◆ Measured in milliseconds with less than 1 second in duration



Army Noise Criteria

- ◆ The Surgeon General has established 85 decibels as the maximum level of continuous unprotected exposure to steady-state noise for 8 hours



Army Noise Exposure Criteria

Exposure Duration per day (hours)	Maximum Exposure level (dB)
8	85
4	90
2	95
1	100
1/2	105

For every 5 decibel noise increase exposure,
time is cut in half

ELO C

- ◆ Action: Identify the three types of hearing loss
- ◆ Condition: Given a list
- ◆ Standard: Select the type of hearing loss, with the causes IAW TC 3-04.93



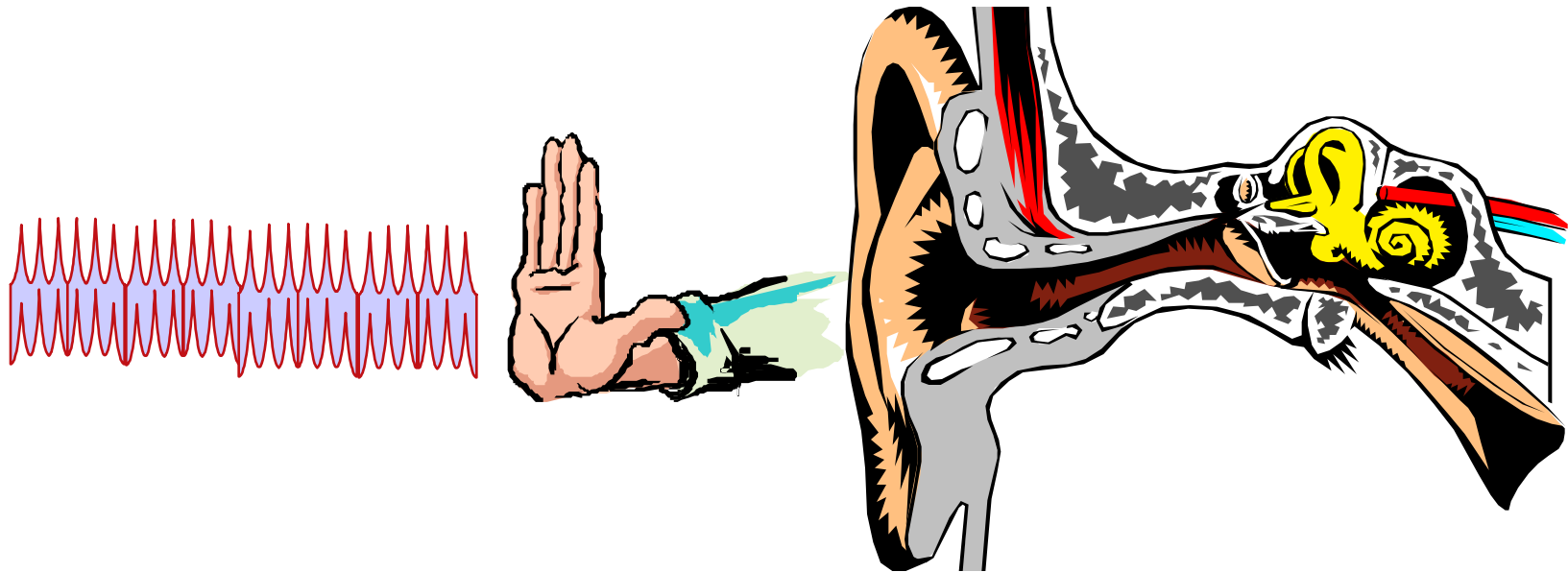
Types of Hearing Loss

- ◆ Conductive Hearing Loss
- ◆ Sensorineural Hearing Loss
- ◆ Mixed



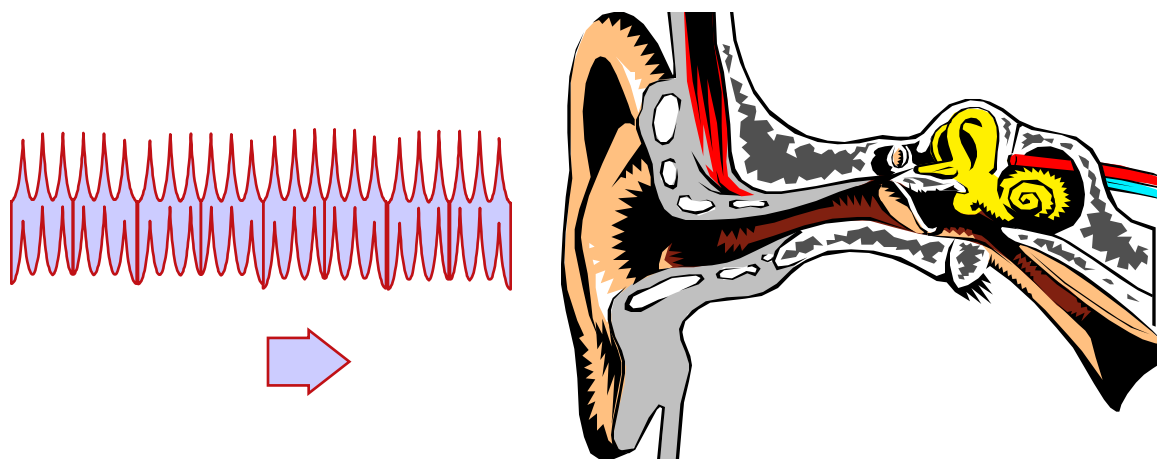
Conductive Hearing Loss

- ◆ Defect or impediment in the external or middle ear
- ◆ Impede with the mechanical transmission of sound to the inner ear



Sensorineural Loss

- ◆ When cochlea is damaged
- ◆ Most frequently produced by noise
- ◆ Occurs in the higher frequencies first
- ◆ Could be associated with aging



Acoustic Trauma

- ◆ Sudden and could cause hearing loss
- ◆ In excess of 140 dB
- ◆ From impulse noise (blast / gunfire)
- ◆ Usually predictable and preventable



Mixed Hearing Loss

- ◆ Combination of conductive and/or sensorineural loss
- ◆ Example: A crewmember with a middle ear infection (conductive) and a high frequency hearing loss (sensorineural)
- ◆ One is treatable, the other is not



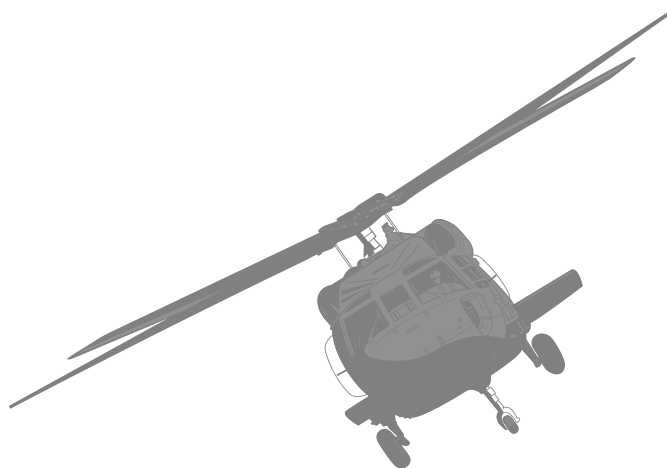
Noise Induced Hearing Loss

- ◆ Temporary Threshold Shift (TTS)
- ◆ Permanent Threshold Shift (PTS)



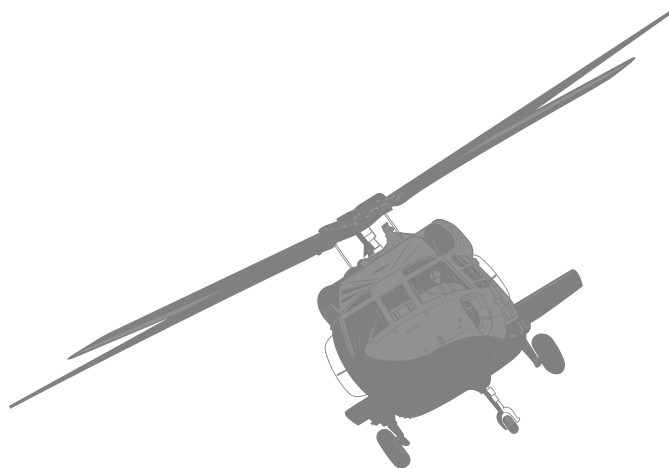
Temporary Threshold Shift (TTS)

- ◆ Single exposure to high level noise
- ◆ May last for few minutes / hours
- ◆ Depends upon frequency, intensity, and duration of the noise
- ◆ Recovery when noise is removed, usually complete



Permanent Threshold Shift (PTS)

- ◆ If continued for 15 hours, eventually permanent loss is induced
- ◆ No recovery when exposure is terminated
- ◆ TTS could become permanent (cannot be predicted)



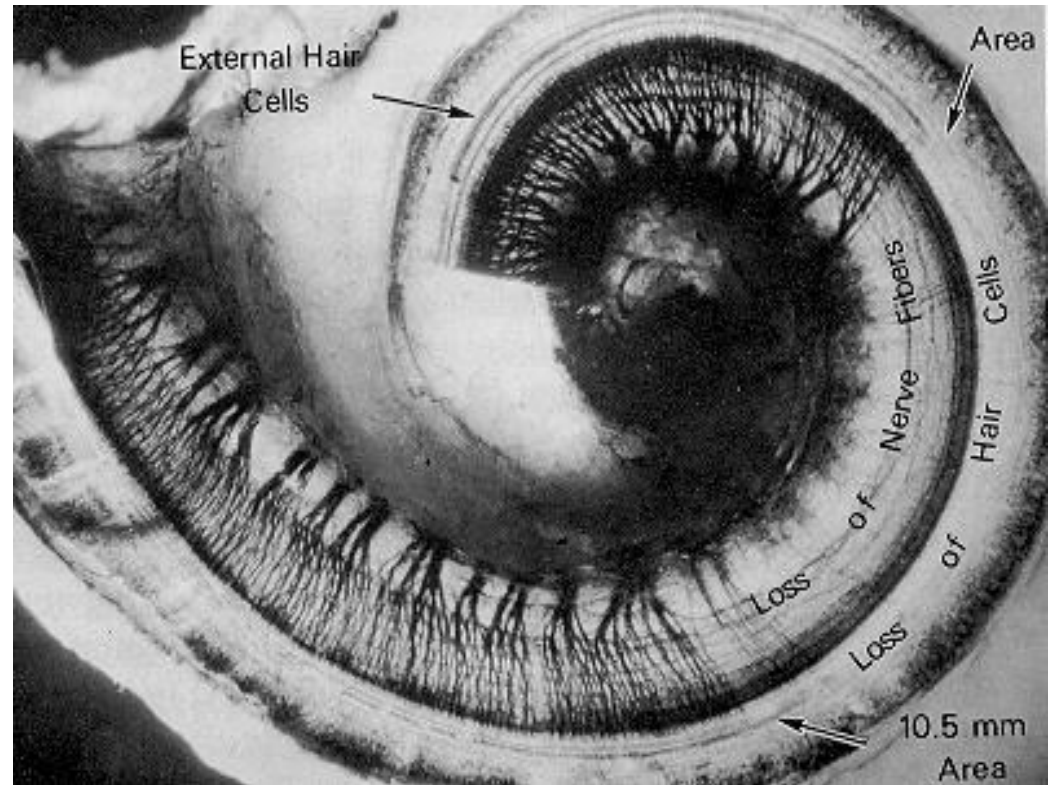
Damaged Hair Cells

Results after
an exposure
of 120dB for
5 hours



Damaged hair cells in the various bundles
means loss of sound perception

Long Term Hair Cells Damage



Prolonged, unprotected exposure to noise could cause irreversible damage

Warning Signs of Hazardous Noise

- ◆ You must raise your voice to be heard
- ◆ You can't hear someone speaking from two feet away
- ◆ Speech around you sounds muffled or dull after leaving a noise area
- ◆ You have pain or ringing on your ears (tinnitus) after exposure to noise



Characteristics of Noise Induced Hearing Loss

- ◆ Insidious and undetectable
- ◆ Noise intensity below 140dB but above 85dB
- ◆ Physical pain not evident
- ◆ Initially higher frequencies affected (3000 to 6000 Hz)



Audiograms

- ◆ Used to determine hearing loss
- ◆ Your first audiogram is a “Reference Audiogram”
- ◆ Considered normal if hearing thresholds are 20 dB or less for all frequencies tested



Initial Evaluation

REFERENCE AUDIOGRAM

ZIP CODE/APO: _____

DOD COMPONENT: ☐ A - ARMY ☐ M - MARINES ☐ SERVICE COMPONENT: ☐ B - REGULAR ☐ G - NATIONAL GUARD ☐ I - OTHER

N - NAVY ☐ F - AIR FORCE ☐ I - OTHER DOD ACTIVITY ☐ F - REGULAR ☐ I - OTHER

SSN: _____ MIDDLE INITIAL: _____

SEX: ☐ M - MALE ☐ F - FEMALE ☐ A - OTHER ☐ year month day

PAY GRADE, UNIFORM SERVICES: _____ GRADE, CIVILIAN: _____ SERVICE DUTY OCCUPATION CODE: _____

MAILING ADDRESS OF ASSIGNMENT: _____

LOCATION - PLACE OF WORK: _____ MAJOR COMMAND: _____ DUTY PHONE: _____

AUDIOMETRY

☐ 1. REFERENCE ESTABLISHED PRIOR TO INITIAL DUTY IN HAZARDOUS NOISE AREAS
2. REFERENCE ESTABLISHED FOLLOWING EXPOSURE IN NOISE DUTIES
3. REFERENCE RE-ESTABLISHED AFTER FOLLOWUP PROGRAM

HEARING THRESHOLD LEVELS OF TEST FREQUENCIES RE: ANSI S3.6

LEFT EAR						RIGHT EAR					
500	1000	2000	3000	4000	6000	500	1000	2000	3000	4000	6000
00	00	15	10	00	10	00	05	10	15	20	10

DATE OF AUDIOGRAM: year month day DAY OF WEEK: ☐ 1-SUN ☐ 2-MON ☐ 3-TUES ☐ 4-WED ☐ 5-THURS ☐ 6-FRI ☐ 7-SAT MIL-TIME-DAY: _____ HOURS SINCE LAST NOISE EXPOSURE: _____ ENT PROBLEM AT TIME OF TEST: ☐ 1 - NO ☐ 2 - YES ☐ 3 - UNKNOWN

EXAMINER

LAST NAME - FIRST NAME - MIDDLE INITIAL: _____ TRAINING CERT. NO.: _____ SSN: _____ SERVICE DUTY OCCUPATION CODE: _____ OFFICE SYMBOL: _____

AUDIOMETER

TYPE: ☐ 1-MANUAL ☐ 2-SELF-RECORDING (automatic) ☐ 3-MICROPROCESSOR MODEL: _____ MANUFACTURER: _____ SERIAL NUMBER: _____ LAST ELECTROACOUSTIC CALIB DATE: year month day

PERSONAL HEARING PROTECTION

TYPE USED: ☐ 1-SINGLE FLANGE (V51R) ☐ 5-NOISE MUFFS ☐ 2-TRIPLE FLANGE ☐ 6-OTHER ☐ 3-HAND FORMED EARPLUGS ☐ 4-EAR CANAL CAPS

EARPLUGS ISSUED: ☐ 1-NO ☐ 2-YES ☐ 3-PREVIOUSLY ISSUED SIZE EARPLUGS: R L ☐ 1-XS ☐ 2-S ☐ 3-M ☐ 4-L ☐ 5-XL

DOUBLE PROTECTION USED: ☐ 1-NO ☐ 2-YES GLASSES WORN (including goggles): ☐ 1-NO ☐ 2-YES FREQUENCY GLASSES WORN: ☐ 1-ALWAYS ☐ 2-SELDOM ☐ 3-N/A

REMARKS: _____

Annual Examination

HEARING CONSERVATION DATA										1. ZIP CODE/APO/FPO/PAS			
(This form is subject to the Privacy Act of 1974 - use Blanket PAS - DD Form 2005)													
2. DOD COMPONENT						3. SERVICE COMPONENT							
A - ARMY		F - AIR FORCE		1 - OTHER		R - REGULAR		G - NATIONAL GUARD					
N - NAVY		M - MARINE CORPS				V - RESERVE		1 - OTHER					
4. SOCIAL SECURITY NUMBER			5. NAME (Last, First, Middle Initial)				6. DATE OF BIRTH			7. SEX			
										M - MALE F - FEMALE			
8. PAY GRADE UNIFORMED SERVICES		9. PAY GRADE CIVILIAN		10. SERVICE DUTY OCCUPATION CODE		11. MAILING ADDRESS OF ASSIGNMENT							
						FT RUCKER AL 36352							
12. LOCATION - PLACE OF WORK						13. MAJOR COMMAND TRADOC		14. DUTY TELEPHONE (Include area code)					
15. AUDIOMETRY		2. PURPOSE		1 - 30 DAY		2 - ANNUAL		3 - TERMINATION		4 - OTHER			
AUDIOMETRIC DATA RE: ANSI S3.6 - 1999		LEFT						RIGHT					
		500	1000	2000	3000	4000	6000	500	1000	2000	3000	4000	6000
b. CURRENT AUDIOGRAM		25	50	65	45	100	90	45	45	55	35	25	55
DATE 1999/11/12													
c. REFERENCE AUDIOGRAM		10M	10M	15M	15M	10M	5M	15M	15M	15M	10M	10M	10M
DATE 1997/04/13													
d. SIGNIFICANT THRESHOLD SHIFT (STS)		e. SUBSEQUENT SHIFT											
2+ 1 - NO 2 - YES		*****>											
f. REMARKS (Include Exposure Data)								g. TYPE OF PERSONAL HEARING PROTECTION USED					
Routinely Noise Exposed, See IH Report for Noise Levels, H-1, Positive STS, I am aware of a change in my hearing and the need to return for further follow-up, Signature								3 1 - SINGLE FLANGE (N51R) 4 - EAR CANAL CAPS 2 - TRIPLE FLANGE 5 - NOISE MUFFS 3 - HAND FORMED EARPLUG 6 - OTHER 7 - NONE					

Degree of Hearing Loss

- ◆ Normal range or no impairment = -10 dB to 15 dB
- ◆ Slight Loss/Minimal loss = 16 dB to 25 dB
- ◆ Mild loss = 26 dB to 40 dB
- ◆ Moderate loss = 41 dB to 55 dB
- ◆ Moderate/Severe loss = 56 dB to 70 dB
- ◆ Severe loss = 71 dB to 90 dB
- ◆ Profound loss = 91 dB or more

ELO D

- ◆ Action: Identify the noise characteristics of military aircraft
- ◆ Condition: Given a list
- ◆ Standard: Select the appropriate noise threat level of military aircraft, and the effect of that level IAW TC 3-04.93

Noise in Army Aircraft (General Findings)

- ◆ Overall noise levels are equal to or exceed 100 dB's
- ◆ Most intense noise below 300 Hz
- ◆ Low frequency noise will produce high frequency hearing loss
- ◆ Must Use Hearing Protection!



Noise in Army Fixed-Wing Aircraft



C-12 ↑ **106 dB**
Exterior Noise level

- ◆ Engines and propellers in close proximity to the cockpit
- ◆ Other fixed-wing aircraft are better insulated to attenuate noise levels

UC-35 (Cessna Citation Ultra)
Cabin noise level 96dB →



Rotary-Wing Aircraft Noise

- ◆ Noise levels equal or exceed 100 dB
- ◆ Originates from engines (power plants), rotor systems and transmissions
- ◆ Observation helicopters (100-103 dB)
- ◆ Attack helicopters (104 dB); increased during missions with weapon systems firing
- ◆ Utility and cargo helicopters (108-112 dB)

Rotary-Wing Aircraft Noise Levels

Aircraft	dB
UH-1H	102
AH-1	105
OH-58C	103
OH-58D	100
CH-47D	112
UH-60A	108
AH-64	104
*TH-67	102

Noise During Air Load Operations

Aircraft	Maximum dB	Pilot-Cruise dB
C-5A	107 dB	85 dB
C-141	94 dB	84 dB
C-130	95 dB	84 dB
C-17	90.7 dB	89.5 dB

Crew members are exposed to noise levels that exceed 85 dB

Wear Hearing Protection!

ELO E

- ◆ Action: Identify methods to protect aircrew members from noise threats
- ◆ Condition: Given a list
- ◆ Standard: Select appropriate protective measures IAW TC 3-04.93



Noise Protection

- ◆ Aircraft design, silent operation or noise suppression
- ◆ Isolate, distance or enclose source (insulate)
- ◆ Personal protective equipment (most economical and practical)
 - ▶ Attenuation: noise reduction amount
 - ▶ Speech intelligibility increased due to noise reduction
 - ▶ Maximum attenuation is ~50 dB; due to bone conduction

Ear Plugs

- ◆ Foam, single flange, and triple flange
- ◆ Inexpensive, easy to carry
- ◆ Attenuation 18 to 45 dB across frequency band, if worn properly
- ◆ Effective when worn with HGU-56, and IHADSS flight helmets



Ear Muffs

- ◆ 10 to 41 dB attenuation across the frequency band
- ◆ Comfortable to wear
- ◆ Ground personnel can lose their hearing too
- ◆ Good control measure to ensure personnel are wearing hearing protection (high visibility)



Headsets

- ◆ Hearing protection as well as radio communication
- ◆ Attenuation could decrease due to damaged ear seals
- ◆ Commonly worn on VIP aircraft
- ◆ Lack crash-worthiness of flight helmet



Protective Helmets (Characteristics) HGU-56

- ◆ Provide both crash and noise attenuation
- ◆ Great protection against higher frequencies
- ◆ Low frequency is the concern in the aviation environment



Protective Helmets (Guidelines) HGU-56

- ◆ Must fit properly, worn correctly
- ◆ Ear cups must be soft, unwrinkled, and tear free
- ◆ Noise attenuation will bring the noise exposure within the confines of damage risk criteria for every Army aircraft **Except UH-60 & CH-47**



Protective Helmets and Ear Plugs

- ◆ If worn in combination, **will provide additional protection from all aircraft noise in the Army inventory**



Combined Hearing Protection



Communication Ear Plug (CEP)

ELO F

- ◆ Action: Identify sources of non-occupational noise exposure
- ◆ Condition: Given a list
- ◆ Standard: Select the noise threat level associated with non-occupational noise IAW TC 3-04.93



Non-Occupational Noise Exposure

- ◆ General aviation flying
- ◆ Weapons firing
 - ▶ Hunting
 - ▶ Target/skeet shooting
- ◆ Moonlighting (off-duty employment)
- ◆ Contemporary music
 - ▶ MP3 players
 - ▶ Personal stereos
- ◆ Hobbies & recreation
- ◆ Household chores

Non-Occupational Noise Exposure Levels

Source	dB
Single engine aircraft	85 dB
Shotgun	130 dB
Bartending	95-110 dB
Music at a club	130 dB
Lawn mower	95-100 dB
Vacuum cleaner	90-100 dB

Check on Learning

◆ What is noise?

Loud, unpleasant, or unwanted sound

◆ What are the three measurable characteristics of sound?

Frequency, Intensity & Duration

◆ What are the short and long term effects of noise?

Annoyance, Speech interference, Fatigue and Hearing loss

Summary

- ◆ Identified terminology associated with sound
- ◆ Identified the effects of noise on the body
- ◆ Identified of the three types of hearing loss
- ◆ Identified the noise characteristics of military aircraft
- ◆ Identified methods to protect aircrew members from noise threats
- ◆ Identified sources of non-occupational noise exposure

ELO G

- ◆ ACTION: Identify vibration terminology
- ◆ CONDITION: Given a list
- ◆ STANDARD: Correctly identify terms associated with vibration IAW TC 3-04.93



Vibration

- ◆ The motion of an object relative to a reference position (object at rest) involving series of oscillations resulting in the displacement and acceleration of the object



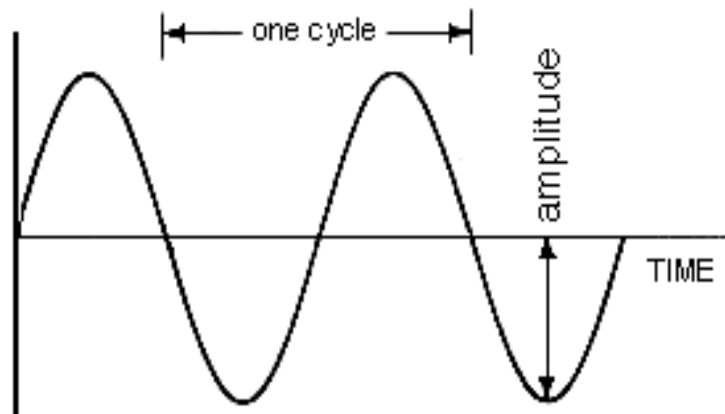
Vibration Terminology

- ◆ Frequency
- ◆ Amplitude
- ◆ Duration
- ◆ Natural Body Resonance
- ◆ Damping



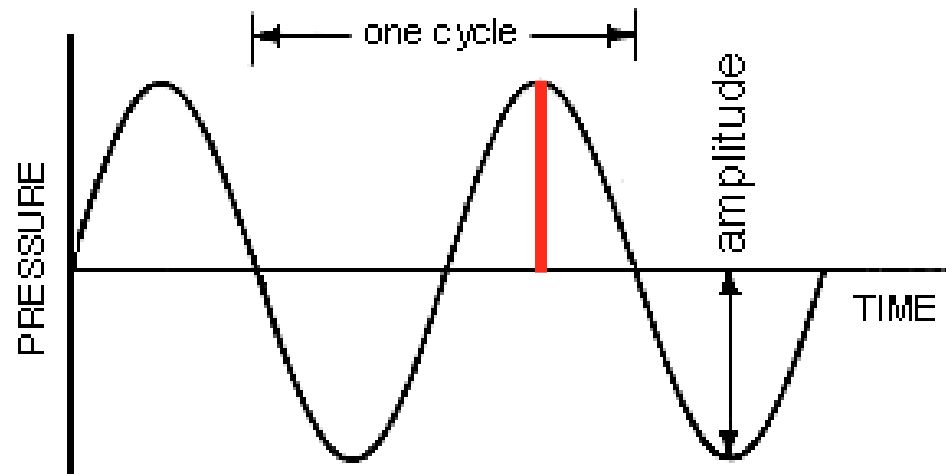
Frequency

- ◆ Number of oscillations of any object in a given time
- ◆ 1 cycle per second (cps) = 1 Hertz (Hz)

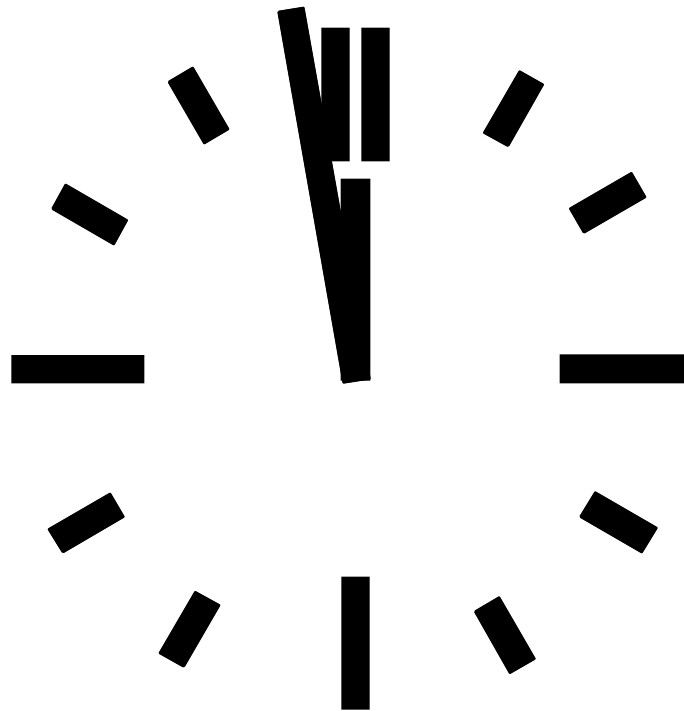


Amplitude

The maximum displacement about a position at rest



Duration



Time of exposure

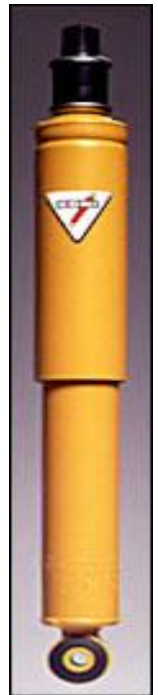
Natural Body Resonance

- ◆ The mechanical amplification of vibration by the body occurring at specific frequencies

Body Part	Resonant Frequency
Whole body	4-8 Hz
Shoulder Girdle	4-8 Hz
Head	25 Hz
Eyes	30-90 Hz

Damping

- ◆ Loss of mechanical energy in a vibrating system
- ◆ Causes the vibration to slow down
- ◆ Body's connective tissue damps vibrations



ELO H

- ◆ ACTION: Identify sources of vibration
- ◆ CONDITION: Given a list
- ◆ STANDARD: Select sources of vibration, and the threat associated with each source IAW TC 3-04.93



Sources of Vibration



Sources of Vibration

- ◆ Increased air speed
- ◆ Internal and external loading
- ◆ Environmental factors (turbulence)
- ◆ Most intense during transition from hover to cruise flight and cruise to hover



ELO I

- ◆ Action: Identify the effects of vibration on human performance during flight
- ◆ Condition: Given a list
- ◆ Standard: Select the appropriate effect on the human body due to vibration IAW TC 3-04.93



Physical Effects (Performance)

- ◆ Simple task completion
- ◆ Manual coordination (Pilot on the Controls)
- ◆ Vision
- ◆ Speech



Manual Coordination

- ◆ Coordination and control “touch” is degraded at 4-8 Hz
- ◆ Aircrew member may over control during turbulence and/or transition from a hover to level flight

Pilot induced
oscillations



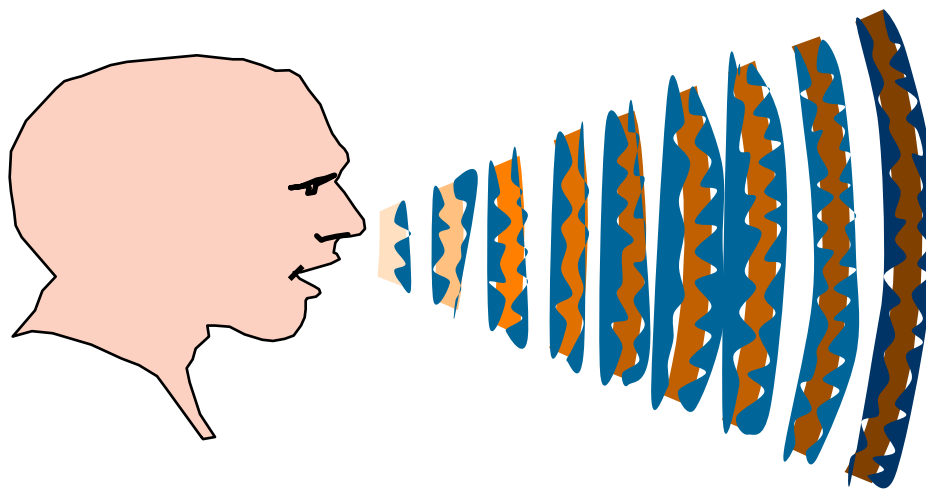
Vision

- ◆ Instrument panel may be difficult to read
- ◆ Helmet mounts start to vibrate at 4-12 Hz



Speech

- ◆ Can be distorted during oscillations of 4-12 Hz
- ◆ Above 12 Hz, speech becomes increasingly difficult to interpret



Physical Effects (Short Term)

- ◆ Fatigue
- ◆ Respiratory effects
- ◆ Circulatory effects
- ◆ Motion sickness
- ◆ Disorientation
- ◆ Pain



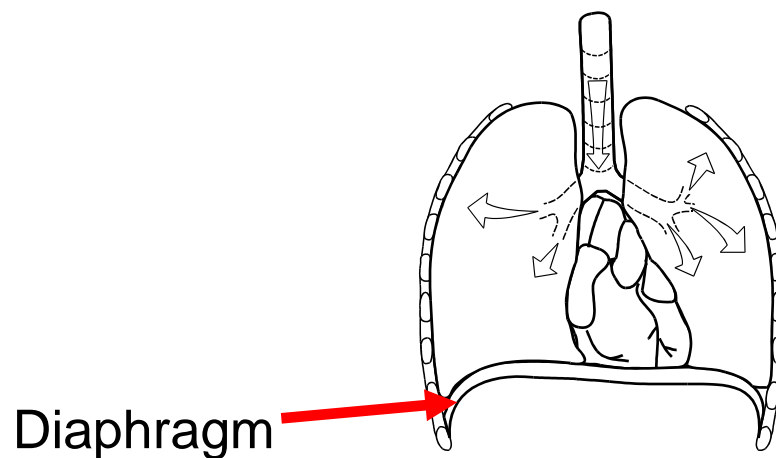
Fatigue

- ◆ Vibration causes the muscle to contract
- ◆ Pressure receptors must constantly measure angular position
- ◆ The receptors respond to vibration by causing contraction or tightening of the muscle to maintain balance and posture

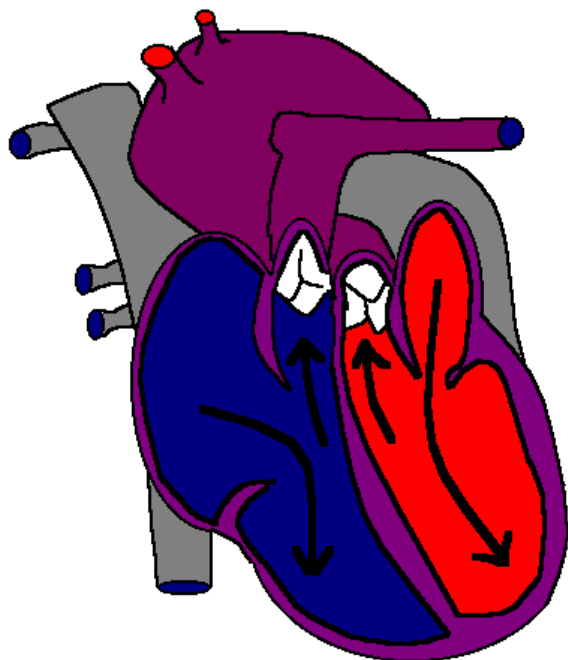


Respiratory Effects

- ◆ Hyperventilation is caused when the diaphragm is vibrated at 4-8 Hz
- ◆ Artificial respiration



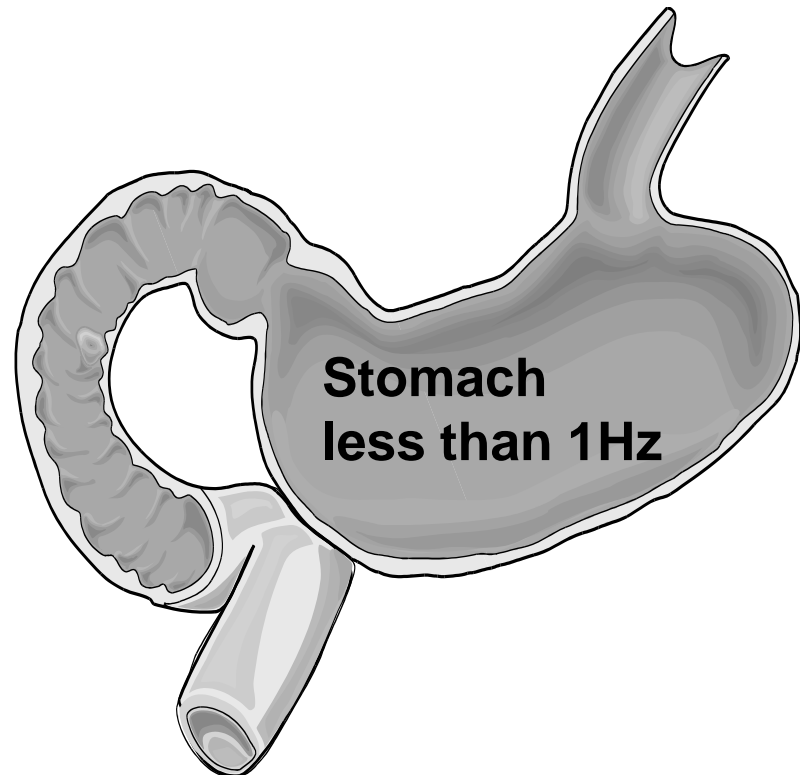
Circulatory Effects



The body interprets vibrations experienced during flying as exercise. Therefore, the muscular effort of bracing against vibration increases pulse rate and blood pressure

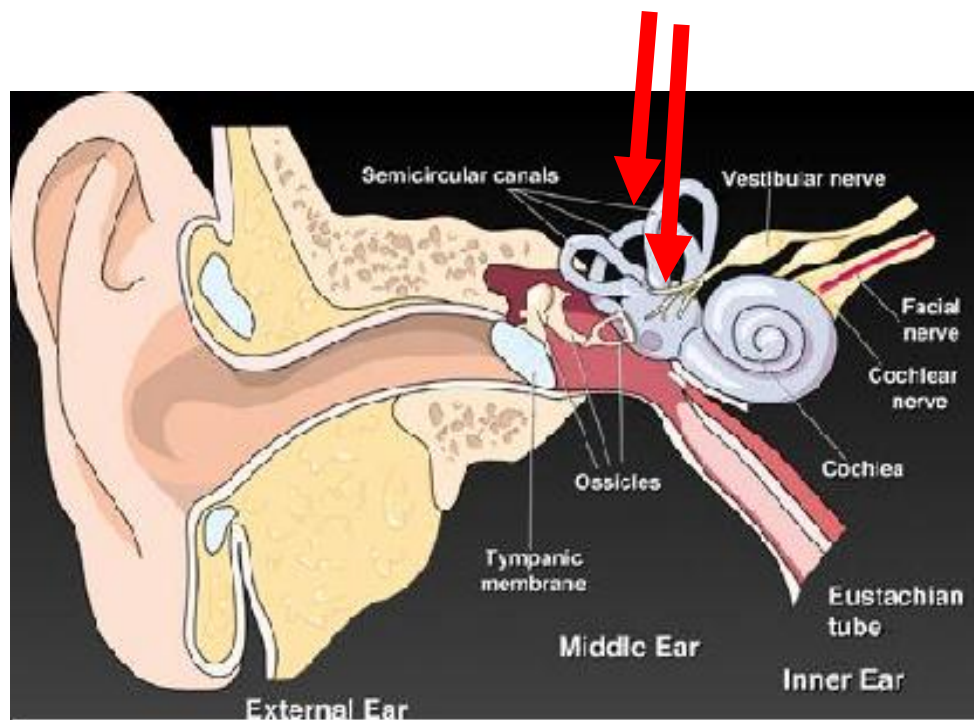
Motion Sickness

- ◆ Frequency of less than 1 Hz
- ◆ Neural Mismatch Theory



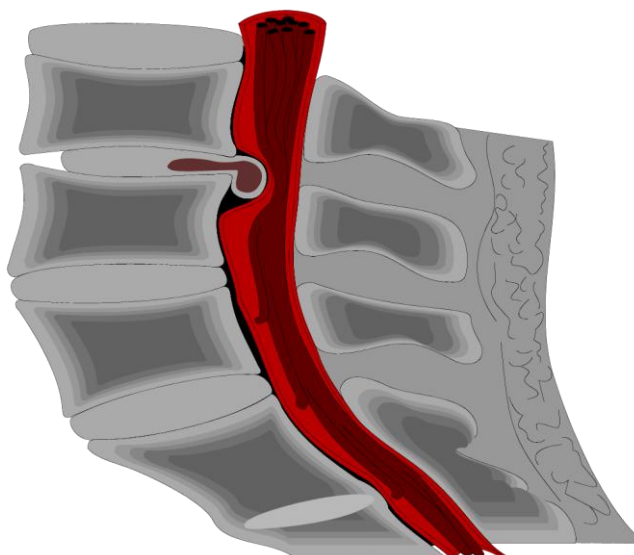
Spatial Disorientation

- ◆ Vibration affects the semicircular canals and the Otolith organs



Pain

- ◆ Pre-existing injuries aggravated by vibration
 - ▶ Stress fractures
 - ▶ Back pain
 - ▶ degenerative disc disease



Long Term Effects of Vibration

- ◆ Raynaud's Disease
- ◆ Backache/back pain
- ◆ Kidney and lung damage

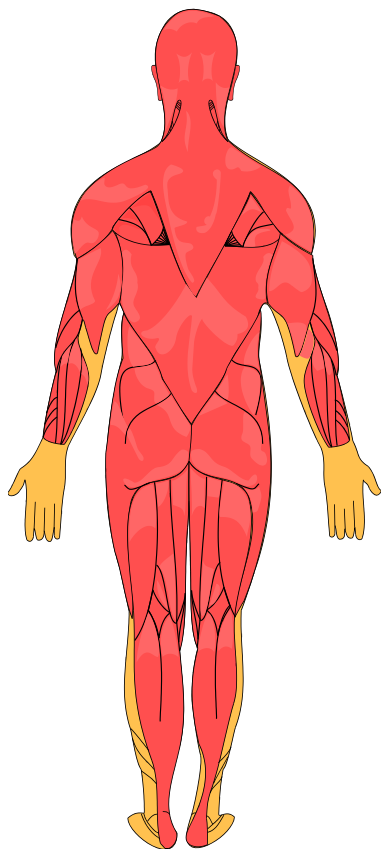


Raynaud's Disease

- ◆ Raynaud's Disease (white finger) - Prolong exposure to vibration
- ◆ Trauma to arterioles and nerve endings in the extremities

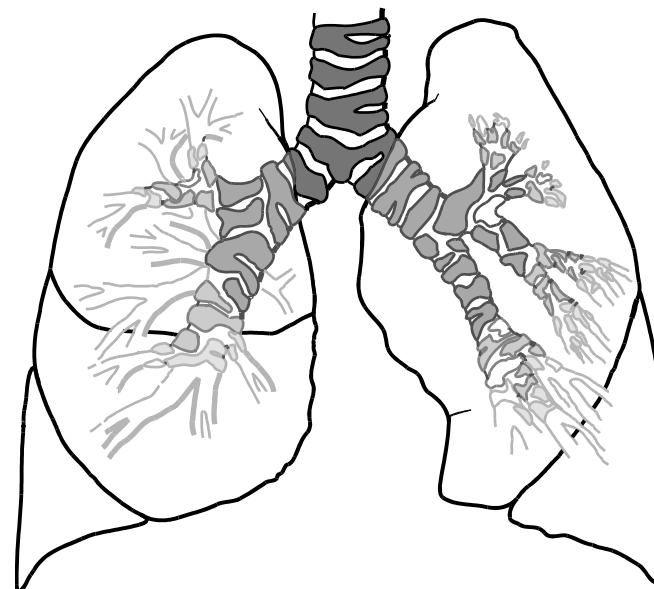
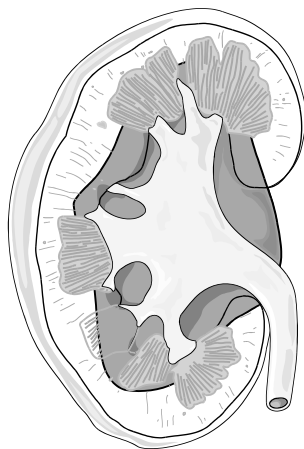


Backache/Back Pain



- ◆ May result at an earlier age than normal
- ◆ The lumbar spine is subjected to higher pressure while sitting
- ◆ Vibration can cause premature degeneration of bone structures due to inadequate blood supply

Kidney and Lung



- ◆ Under scientific study
- ◆ Blood in urine is a sign of overexposure
- ◆ Lung damage results from overexposure (resonant frequencies)

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- ◆ Action: Identify methods to protect aircrew members from the effects of vibration
- ◆ Condition: Given a list
- ◆ Standard: Select the appropriate method(s) used to protect aircrew members from the effects of vibration IAW TC 3-04.93

Reduction of Vibration Effects

- ◆ Good posture during flight promotes good circulation
- ◆ Restraint systems provide protection against high magnitude vibration during extreme turbulence

WARNING

Body supports reduce discomfort but could cause injury during a crash sequence

- ◆ Maintain your aircraft (rotor blade tracking/balancing)

Reduction of Vibration Effects

- ◆ Isolate crewmembers, passengers, patients from aircraft structures
- ◆ Use of seatbelts
- ◆ Limit exposure time; short flights/frequent breaks rather than long flights (if mission permits)
- ◆ Let the aircraft do the work
 - ▶ Avoid tight grip on flight controls
 - ▶ Transmission of vibration through flight controls

Maintain Excellent Physical Condition

- ◆ Fat multiplies vibration, muscles dampen vibration
- ◆ Decreases the effects of fatigue
- ◆ Maintain sufficient hydration
- ◆ Dehydration with vibration can cause fatigue twice as fast and increase recovery time



Check on Learning

◆ What is Vibration?

The motion of an object relative to a reference position (object at rest) involving series of oscillations resulting in the displacement and acceleration of the object

◆ What is Frequency?

Number of oscillations of any object in a given time

◆ What are some short and long term effects of Vibration?

Fatigue, Disorientation, Pain, Backache, Raynaud's

◆ How do we protect our self from Vibration?

Limit exposure, Good posture, Isolate body from vibrating structure, Maintain physical fitness, Hydrate, Maintain Aircraft

Summary

- ◆ Identified vibration terminology
- ◆ Identified sources of vibration
- ◆ Identified the effects of vibration on human performance during flight
- ◆ Identified methods to protect aircrew members from the effects of vibration

